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TRICKLING FILTER TREATMENT OF FRUIT PROCESSING WASTE WATERS

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TRICKLING FILTER TREATMENT OF FRUIT PROCESSING WASTEWATERS

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by

National Canners Association
Research Foundation
1950 Sixth Street
Berkeley, California 94710

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September, 1971

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ABSTRACT

Two high rate trickling filters were evaluated for treating fruit canning liquid wastes; one was 7.5 feet deep and had provision for heating the treated waste and for forced aeration; the other was 21.5 feet deep and was operated at ambient temperatures and with natural aeration; both were packed with a high void ratio plastic medium.

Nitrogen added to the cannery waste improved the removal of BOD and COD. In the absence of added nitrogen a thick fungal slime developed with odors characteristic of anaerobic microbial action. The need for adding phosphorous was not demonstrated.

More often than not, percent removals declined with increasing organic loadings; the pounds of BOD or of COD removed per unit volume increased with higher loadings.

Elevated temperatures were not consistently shown to improve the performance of the experimental filter.

Forced aeration was not proven to be beneficial in the filter treatment, but increased aeration maintained higher levels of dissolved oxygen in the effluent.

The top third of the 21.5 foot trickling filter accomplished 80% of the filter's total BOD removal under a light hydraulic loading. The top third removed a much higher percentage of reducing sugars than of total BOD, 67% compared to 32%.

The natural aeration filter maintained a slightly higher dissolved oxygen concentration in the effluent at all three tested depths than did the experimental filter with 300 cubic feet per minute of forced aeration.

Under the conditions of this study, increasing the depth of the filter medium beyond 14 feet added very little to the filter's performance.

This report is submitted in fulfillment of Project 12060 EAE under the partial sponsorship of the Office of Research and Monitoring, Environmental Protection Agency.

CONTENTS

Section		Page
I	Recommendations	1
II	Introduction	3
	Purpose and Scope of the Project	3
	Background	3
	Procedures	5
	Equipment	5
	Sampling and determinations	11
	Operations	14
III	Discussion	17
	Nutrients	18
	Loading	19
	Temperature	19
	Aeration	20
	Effect on pH	20
	Filter Depth	20
IV	Acknowledgements	23
V	References	25
VI	Glossary	27
VII	Appendices	29
	A. Laboratory Methods	29
	B. Detailed Data	29

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LIST OF FIGURES

Figure		Page
1	Single bundle of plastic packing medium	6
2	Schematic drawing of forced aeration, controlled temperature trickling filter, first series	7
3	Schematic drawing of forced aeration, controlled temperature trickling filter, second series	8
4	Front view - pilot trickling filter	9
5	Side view - pilot trickling filter	10
6	Schematic diagram of high rate trickling filter treatment system	12
7	Overall view of the trickling filter system	13

LIST OF TABLES

Number		Page
1	Operating variables and BOD removals	16
2	COD and recalculated BOD removals	17
3	Trickling filter performance at three depths	21
4	Natural aeration trickling filter, first series	30
5	Forced aeration trickling filter, first series	31
6	Natural aeration trickling filter, second series	32
7	Natural aeration trickling filter, second series, depth comparisons	34
8	Forced aeration trickling filter, second series	36

SECTION I

RECOMMENDATIONS

Additional performance data are needed on the operation of trickling filters for canning waste treatment (1) at elevated temperatures with carefully controlled heating and adequate nutrient addition; and (2) with forced aeration including rates above 3.6 cubic feet of air per cubic foot of filter medium per minute.

More operational and maintenance data are needed to relate costs to BOD removals under varying conditions of aeration and temperatures. Additional information on the performance of trickling filters at different depths of the plastic medium should be collected, using a range of hydraulic and organic loadings.

The micro-flora on the packing medium should be studied with relation to (1) BOD removal efficiencies at different temperatures, filter depths, and other operating conditions, and (2) nutrient requirements for optimum performance.

SECTION II

INTRODUCTION

PURPOSE AND SCOPE OF THE PROJECT

The purpose of this project was to evaluate and compare the performance of two high rate trickling filter systems in reducing the pollutional capacity of liquid wastes from fruit canning operations.

The scope of the project included locating the units at a cannery and modifying them for operation on fruit processing waste water. Modifications included the updating of schematic drawings, installation of insulation material, procurement of a heating system, procurement of a nutrient feed system, and replacement of the packing medium in one of the filters.

BACKGROUND

No actual filtering of particles from the waste stream is performed by trickling filters. The waste water, introduced at the top of the filter, percolates down through the packing medium. During the contact time between the film of water and the slime growth on the filter medium, organic compounds are subjected to enzymatic breakdown and utilization. The slime microfloras use the organic compounds as energy sources in maintaining cell growth. When the filter is operated as a roughing filter, providing only partial treatment to the waste water, the effluent will have a reduced potential capacity for causing water pollution if discharged to a stream or will require less treatment if discharged to a municipal treatment facility.

The treatment of combined domestic and industrial wastes by trickling filters is now and has been a standard practice for many years. When the design loads of a conventional rock filled trickling filter system are not appreciably exceeded, the results are usually satisfactory (2). Generally, the success of trickling filters depends on good operational control in feeding a balanced waste that is uniform in volume and composition.

The treatment of food canning wastes by the trickling filter method has had a long and varied history. Under certain optimum conditions,

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the system has been successful (1, 9). Many investigators have experienced little success with conventional rock filled filters (1, 2). Several reasons have been advanced for the failure of the rock filter in providing adequate treatment to food wastes.

Canning operations may necessitate a sudden change in the volume discharged or produce a sudden change in the character of the waste. The most frequent change in the nature of the effluent is a sudden increase in alkalinity or acidity. Related to these changes is the possible stop and go nature of plant operations caused by fluctuating arrival of the raw product. Preseason attempts to build up the necessary microbial growth are rarely successful as there is a need for a continuous application of waste over the filter medium. The need to maintain optimum slime growth throughout the season cannot usually be fulfilled by normal cannery operations.

Another undesirable characteristic of fruit canning wastes is the deficiency of the waste in certain microbial nutrients such as nitrogen and possibly phosphorous. In addition to the waste being deficient in certain nutrients, fruit waste contains a high concentration of sugars and acids. These simple compounds are readily degraded by the micro-organisms and as such exert a high immediate oxygen demand. Conventional rock filters are not able to satisfy this immediate oxygen demand, especially under heavy organic loadings.

In recent years significant changes have been made in the basic principles of trickling filter treatment of wastes. One of the most important has been the development of plastic media as a substitute for rock. Many investigators (6, 7, 10) have experienced great success with plastic filled trickling filters. Much of the early work done in England is described in detail by Chipperfield (8). Germain (4) and Stack (3) outlined work done in this country, tracing the development of synthetic media for use in trickling filters. The National Canners Association has evaluated the application of plastic filled trickling filters in treating food canning wastes. The results of these studies, using a small pilot scale trickling filter system, have been reported (5).

The urgency for the development of information regarding the treatment of industrial wastes is repeatedly emphasized by demands for improvements in the quality of our environment. The demand for pollution abatement means less discharge of pollutants into natural

water courses and improvements in the efficiency of municipal treatment systems. To enable canners to meet these demands, comprehensive information must be developed for the various treatment methods applicable to food processing wastes. It appears that plastic filled trickling filters have a greater potential in satisfying the immediate oxygen demand of food waste than have rock filled trickling filters.

This report discusses results obtained from a two year study of a trickling filter using forced aeration and controlled temperature and a trickling filter using natural aeration.

PROCEDURES

Equipment

A pilot scale forced aeration-controlled temperature trickling filter system used in the study was developed by the Aerojet-General Corporation to treat up to 10,000 gallons of raw sewage per day. It consisted of a treatment column 14 feet deep and a reservoir tank 6 feet deep, both cylindrical and 3.75 feet in diameter, with meters, heaters, pumps, and piping.

The treatment column was packed with a honeycombed polyvinyl chloride medium, Surfpac, registered by Dow Chemical Company; see Figure 1. The medium is welded into modules about 19x21x39 inches in dimensions, some of them cut to fit the cylindrical shape of the column, has 27 square feet of surface per cubic foot, and has a volumetric void ratio of 0.94. The column packing was 7.5 feet deep, with a cross sectional area of 11.1 square feet, giving 83 cubic feet of treatment volume.

Waste to be treated was collected in one section of a wet well sump, and was pumped from the sump to a reservoir in the first series of tests. In the second series, two 55-gallon drums preceded the sump, and the reservoir received its flow from the second drum. The primary waste flow was pumped from the reservoir to the top of the column. The recycle flow was collected at the bottom of the column and pumped to the top. The primary and recycle flows were distributed over the surface of the medium by separate fixed nozzles. Nutrient could be added to the recycle flow.

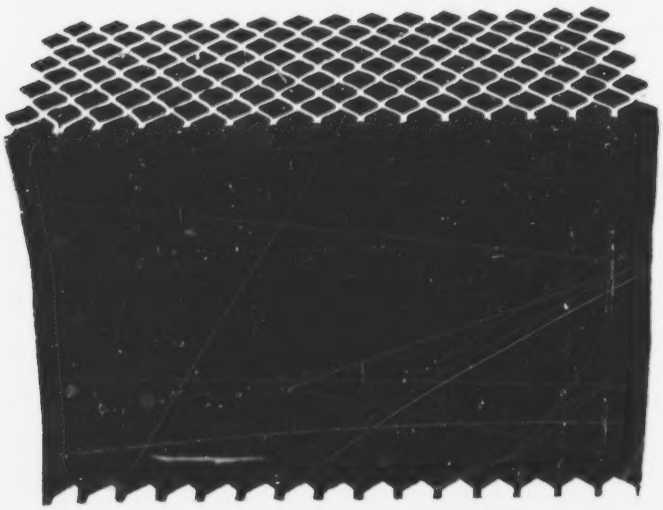

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Fig. 1 Single Bundle of Plastic Packing Medium

In the elevated temperature runs, the waste was heated in the reservoir tank by a steam plate coil in the first series of experimental runs and by direct steam injection in the second. In the second series the injected air was also heated. The treatment column and the reservoir were insulated tc reduce heat loss with black, 1/4 inch, closed cell neoprene; the pipes were insulated with fiber glass wrappings. Thermometers were placed in the column and in the reservoir.

A blower forced air into the bottom of the column. Air flow was measured at an orifice plate in a vent pipe at the top of the column in the first series and after the blower in the second.

Schematic drawings of the system as modified for the two series of tests are in Figures 2 and 3, and photographs of the unit in Figures 4 and 5.

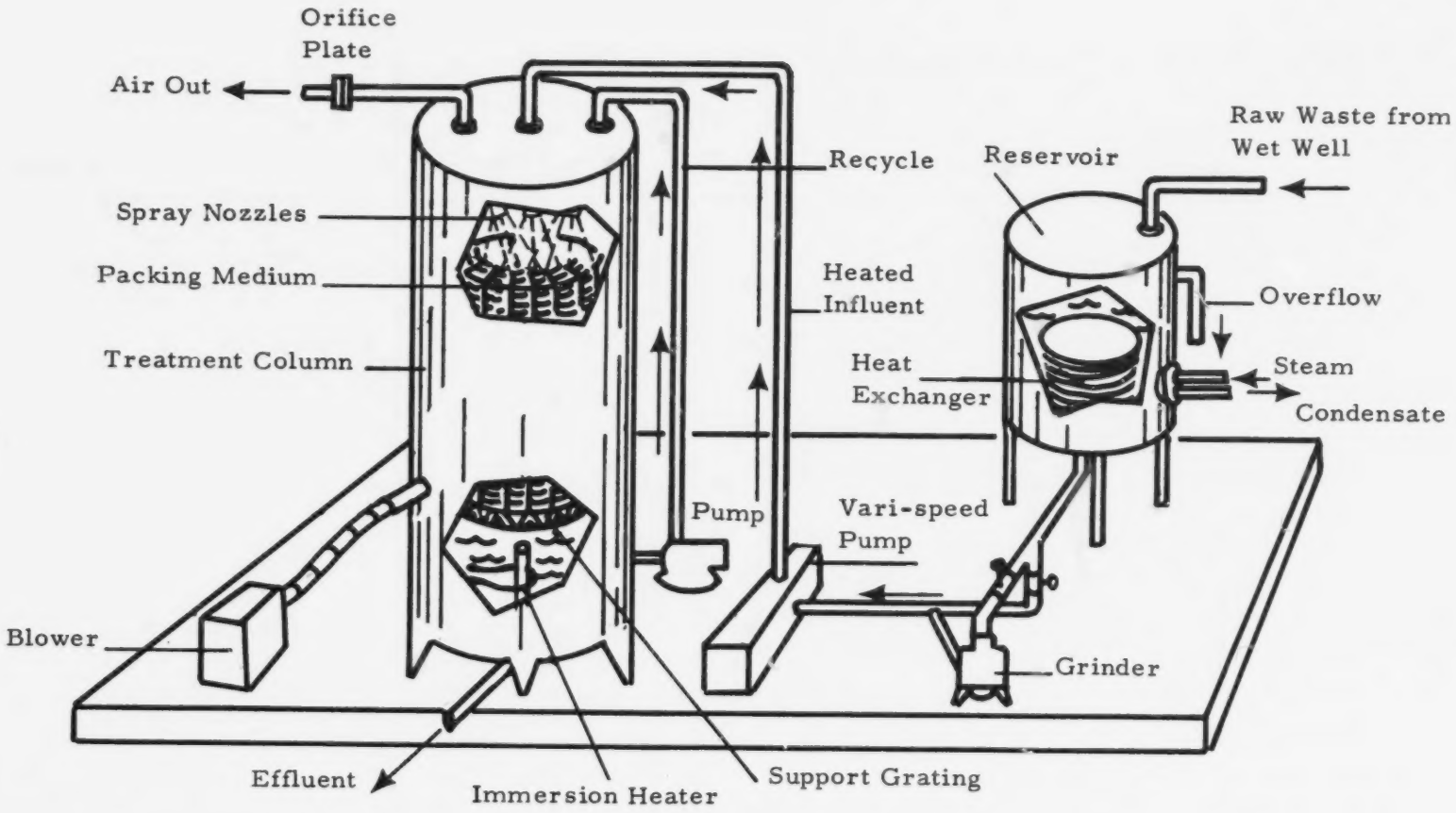

Figure 2 Schematic Drawing of Forced Aeration, Controlled Temperature Trickling Filter, First Series

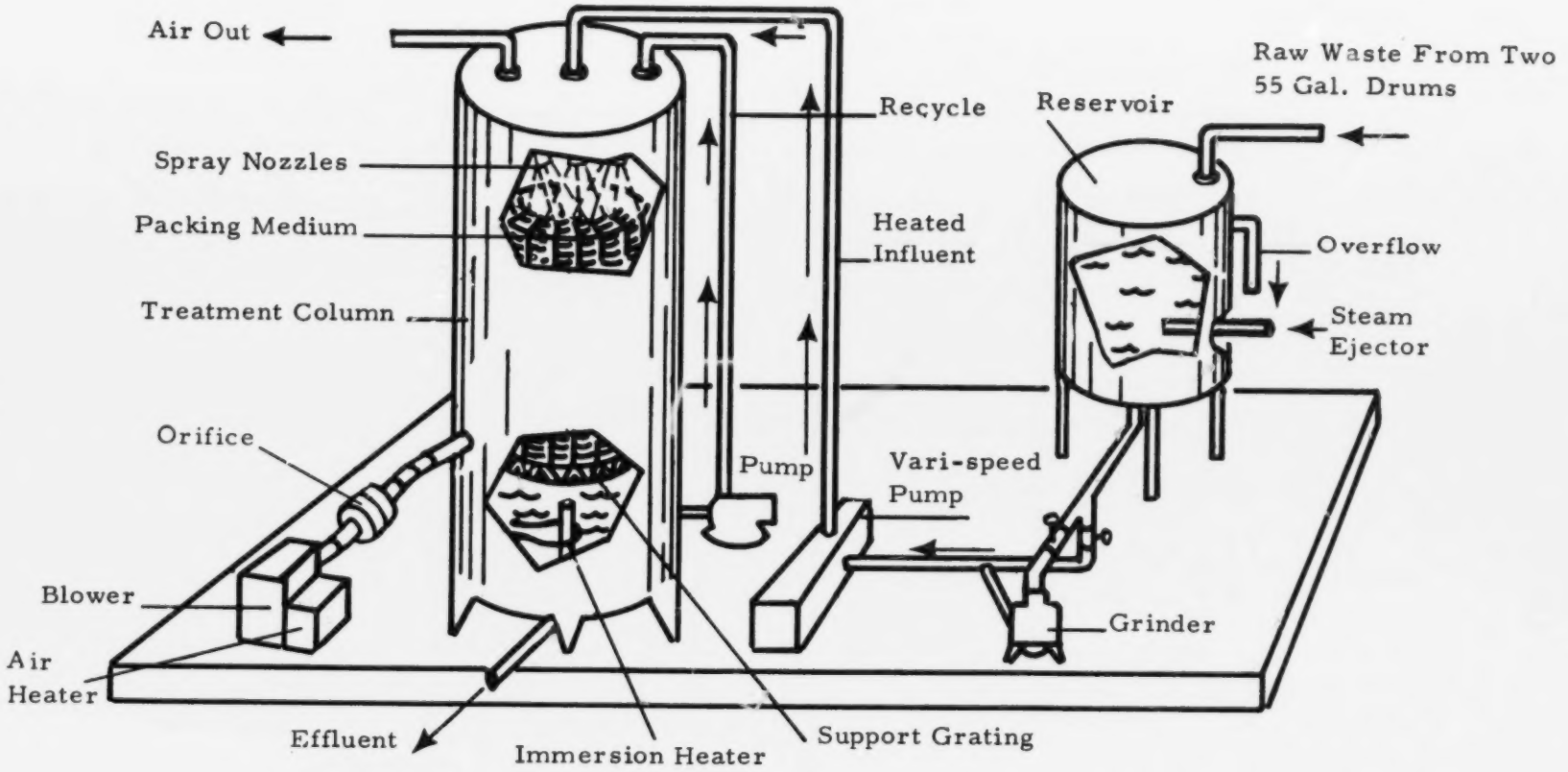

Figure 3 Schematic Drawing of Forced Aeration, Controlled Temperature Trickling Filter, Second Series

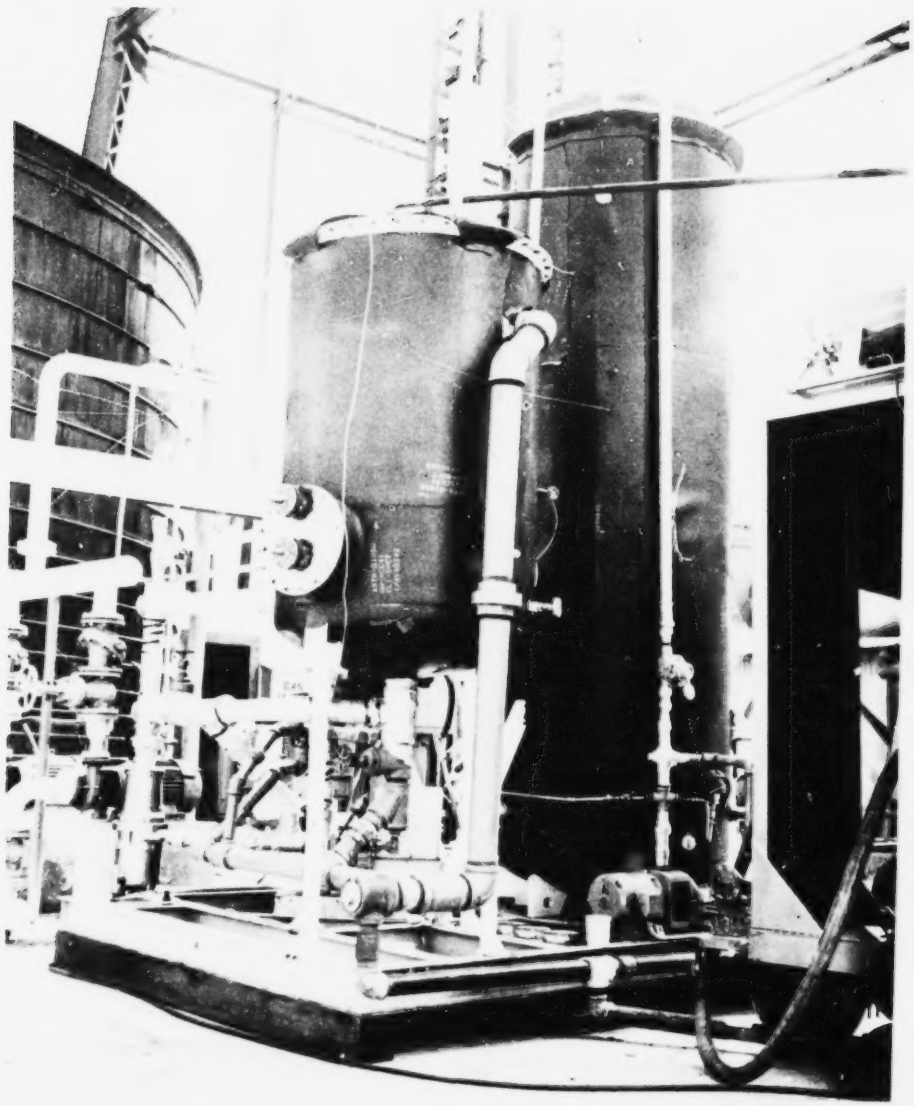

Figure 4 Front View - Pilot Trickling Filter

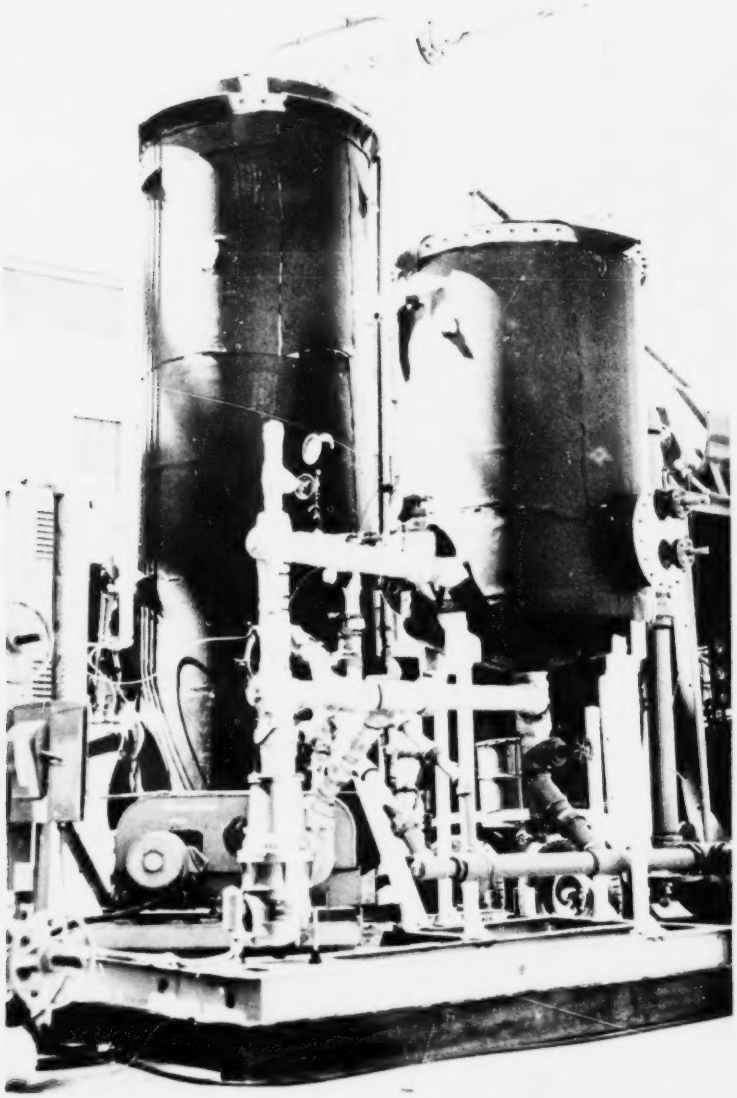

Figure 5 Side View - Pilot Trickling Filter

The natural aeration trickling filter was a larger unit designed and built with the help of the Engineering Section of the Del Monte Corporation. The treatment column was 29 feet deep and 12 feet in diameter; it was packed 21.5 feet deep with the same plastic medium as was used in the forced aeration filter, giving 113 square feet of surface and 2410 cubic feet of treatment volume. The medium is self-supporting to a depth of 21.5 feet and therefore no intermediate support was needed. Eighteen 4-inch ports allowed air to enter the bottom of the column.

The waste flow from the cannery entered one side of a wet well sump 5.7 feet in diameter and 10 feet deep. The sump was divided equally in two by a baffle that extended to 6 inches from the bottom. Waste from the inlet side was pumped to the top of the column and treated waste was returned to the other side of the sump, from which waste was carried away by overflow. A larger flow was pumped to the filter than entered the system from the cannery; the excess constituted the recycle volume. (For example, if 100 gpm of fresh waste entered the sump and 200 gpm was pumped to the filter, the ratio of fresh to recycled flow was 1:1.) The waste was evenly distributed at the top of the filter from four, notched, V-shaped troughs rotating at 2 RPM.

A schematic drawing and a photograph of this unit are in Figures 6 and 7, and additional details are in reference 11.

Sampling and Determinations

Grab samples of the influent and effluent flows were secured every two hours from the forced aeration filter and every four hours from the natural aeration filter. The samples were refrigerated and those from each day's run (of 16 or fewer hours) were composited. Except for the first series of runs from the forced aeration unit, half of each composite was filtered through cotton or glass wool. The composites were then held frozen until they were tested in the laboratory. The filtered samples were used for BOD and COD determinations; the unfiltered samples, for suspended solids. The filtering was to eliminate possible effects on BOD or COD of cells ruptured by freezing. For the second series of runs sampling points at the 7.2 and 14.4 foot depths of the plastic medium in the natural aeration unit were added; the 7.2 foot depth sample was for direct comparison to the effluent from the total depth of the forced aeration filter.

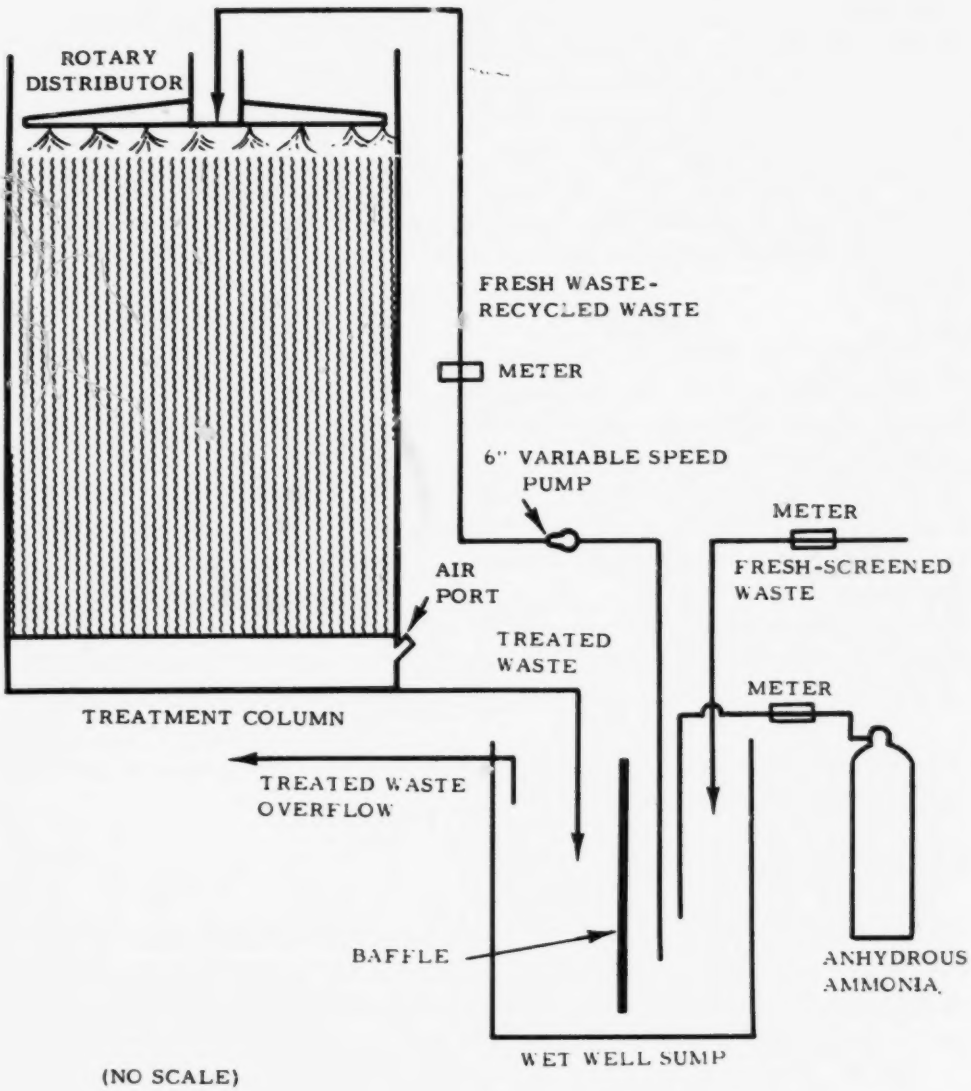

Figure 6 Schematic Diagram of High Rate Trickling Filter Treatment System

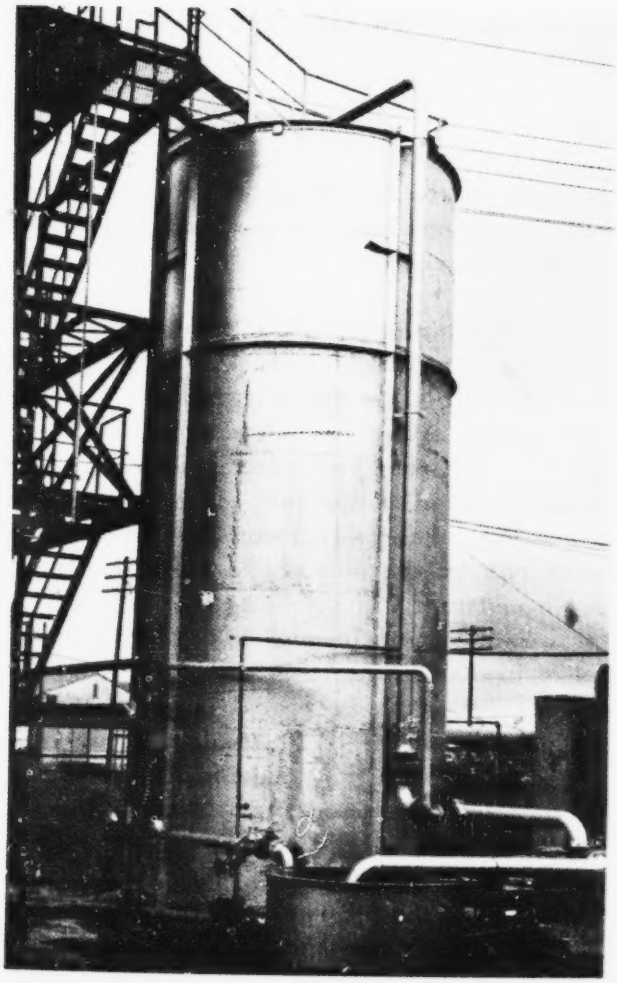

Figure 7 Overall View of the Trickling Filter System

Each sample was analyzed for BOD, COD, suspended solids, and pH. Influent and effluent dissolved oxygen were measured in the morning and in the afternoon starting part way through the second series of runs. The laboratory methods are referenced in the Appendix. Temperatures and air pressures for the forced aeration system were recorded every two hours; flow rates for the natural aeration unit were adjusted daily.

Operations

A portion of the liquid waste flow from canning cling peaches and fruit cocktail was used in the experiments after it had passed through a 20-mesh rectangular screen.

Operating variables are summarized in Table 1, which also lists influent characteristics and BOD removals. The nominal hydraulic loading rates of fresh and of recycled waste are given in gallons per minute per square foot of filter cross section. Forced air, where used, is in standard cubic feet per minute (SCFM). The natural aeration filter was operated at ambient temperatures, presumably at about the level of the forced aeration filter when the latter was not heated. Temperatures (of the influent to the column) above 100 degrees came from heating. The pH and the suspended solids (in ppm) of the fresh waste and of the effluent from the filters are listed. The organic load of the fresh waste is given as pounds of BOD per 1000 cubic feet per day; and the removal is summarized in the same units and as a percentage of the fresh load. Nitrogen as anhydrous ammonia was added to the natural aeration filter; nitrogen and phosphorous as di-ammonium phosphate were used in the forced aeration filter, as noted in the table.

The values in Table 1 are the averages of the several days' runs under each of the listed sets of conditi ons. Averaged daily observations are in Appendix B; also tabulated there are data on the concentrations of BOD and COD, pounds and percent removal of COD, influent and effluent dissolved oxygen, and the temperature of the effluent from the forced aeration filter.

At start-up the forced aeration filter was fed 0.45 and 0.75 gallons per minute per square foot of fresh and of recycled waste, respectively; and the natural aeration filter, 0.35 and 0.88 gpm/sq ft. Sufficient microbial slime developed in four or five days to consider the units operational.

Hydraulic loadings of the fresh and recycle streams were nominally as listed in the tables. Intermittant blocked flows and breakdowns caused some fluctuations. Nitrogen, when used, was added at a ratio calculated to approximate one part of nitrogen to 20 parts of BOD removed; phosphorous, in the forced aeration filter only, at one part of phosphorous to 100 parts of BOD removed. Mechanical difficulties caused variations in the quantities of nutrients added. In particular, nutrient addition to the natural aeration filter fell off at the end of the first series of runs, and to the forced aeration filter at the end of the second series.

Problems in maintaining elevated temperatures are described in the discussion of temperature on page 19. The products being canned and the strength of the plant waste stream varied from day to day. The floras in the filter slimes were not studied systematically so that generally their composition could not be related to removal efficiencies and its change over time is not known.

Table 1. Operating Variables and BOD Removals

gpm/sq ft		SCFM		pH		ppm SS		BOD lbs *		BOD%	
fresh	recyc.	air	temp.	fresh	effl.	fresh	effl.	fresh	removed	removed	Notes
Natural aeration filter, first series, 21.5 ft. depth											
0.66	0.66	-	amb.	6.0	6.0	480	540	640	300	47	
.88	.88	-	"	7.1	5.3	670	940	940	160	17	fungus, odor
.88	.88	-	"	6.9	6.6	710	1030	1100	360	31	NH_3 added
1.55	.88	-	"	6.3	5.5	680	600	1720	270	19	NH_3 deficient
Forced aeration filter, first series											
0.42	0.72	300	83	6.7	5.5	650	850	1240	270	20	
.81	.86	300	83	6.2	5.3	-	-	2200	500	20	
.41	1.34	300	110	5.8	5.0	710	1140	1340	330	25	N and P added
.73	.99	300	111	6.6	5.2	620	1000	2120	100	5	do.
.98	1.16	300	110	6.9	5.7	720	1390	3170	770	25	do.
1.20	.97	300	112	7.8	6.6	870	910	3510	1140	32	do.
Natural aeration, second series, 7.2 ft. depth											
0.44	0.44	-	amb	8.4	8.2	450	420	1550	580	42	NH_3 added
.44	.44	-	"	7.6	7.8	550	730	1730	660	38	do.
.44	.44	-	"	7.8	7.7	720	1240	1860	710	38	do.
.44	.44	-	"	7.7	7.7	810	1450	1830	620	33	do.
.44	.44	-	"	7.2	6.3	770	2020	1860	500	27	do.
.44	.44	-	"	7.8	6.3	670	1540	1810	510	31	do.
Forced aeration filter, second series											
0.55	1.06	100	81	8.4	8.1	450	530	1860	240	13	N and P added
.44	1.08	200	80	7.6	5.8	550	880	1660	240	15	do.
.40	1.03	300	80	7.8	5.9	720	870	1570	330	21	do.
.50	.92	100	117	7.7	6.0	810	2070	2010	350	18	do.
.52	.90	200	117	7.2	6.1	770	790	2110	310	15	nutrient deficient
.49	.90	300	106	7.8	6.0	670	570	1920	240	13	do.

* Pounds/1000 cubic feet/day

SECTION III

DISCUSSION

The observations resulting from the study are summarized in Table 1 and detailed in Appendix B.

On many days in the first series of runs unexpected organic concentrations were observed in the effluent from the filters: (1) BOD was close to or higher than COD instead of much lower, as expected and as observed in the fresh waste and in the effluent samples of the second series; and (2) effluent BOD exceeded the fresh waste BOD in some runs. In two instances it appears that the influent BOD determination was incorrectly low (770 and 800 ppm when the COD was 2980 and 2900, respectively); these data have been omitted from further calculations. On the other days, the discrepant results seem to be excessively high BOD concentrations in the effluent, since the fresh waste BOD's were compatible both with the concurrent COD's and with the BOD's observed on other days. BOD loadings and removals in the forced aeration filter, recalculated by omitting the discrepant observations, are in Table 2; COD figures are listed for comparison.

Table 2. COD and Recalculated BOD Removals

BOD lbs *		BOD%	COD lbs. *		COD%	
fresh	removv.	removv.	fresh	removv.	removv.	Notes
1170	200	17	1820	710	38	no nutrient, amb. temp.
2160	310	15	3860	1520	40	" " " "
1160	270	23	1880	920	50	N & P added, elev. temp.
2170	500	23	3290	1670	52	" " " " "
2880	660	23	4870	1890	39	" " " " "
3510	1140	32	5720	2280	39	" " " " "

* Pounds/1000 cubic feet/day

Another possible explanation for the discrepant results is that the character of the filter effluents was different from that ordinarily found. Most of the discrepant runs were during the periods of increasing filter loadings without added nutrients and the periods

immediately following these when nutrients were added. The type of slime in at least the natural aeration filter changed twice at about these times, but the microflora was not studied in much detail. The ratio of COD to BOD can be changed in the observed direction by partial treatment of food processing wastes. The COD method used during the first series of runs is especially subject to false low readings of partially oxidized wastes; the lower temperature at which the test is run does not result in complete oxidation of complex organic molecules. For the second series an improved COD method was used. This tends to explain the fact that COD removals were higher than BOD removals in the first but not in the second series. However, it does not explain the runs when the effluent BOD's exceeded the fresh waste BOD's. Since some removal of BOD was expected even during inefficient operation, the explanation via inaccurate effluent COD determinations is considered unlikely.

NUTRIENTS

The necessity of adding nutrients, at least nitrogen, to fruit wastes for efficient pollution removals was well demonstrated. In the first series, the natural aeration filter was run for three weeks without added nutrients. At first the performance of the filter was good, but with time a heavy fungal growth was established on the packing medium and objectionable odors developed; the performance of the filter decreased noticeably. The thick growth probably produced anaerobic conditions which caused the odor. Anhydrous ammonia was then fed into the filter at about one pound of nitrogen per 20 pounds of BOD removed. Within three or four days the heavy fungal slime was replaced by a thin, translucent film of motile bacteria. The effluent changed in appearance to that of an activated sludge effluent, and its floc particles settled readily. BOD removal increased from 17% before to 31% after the addition of nitrogen. During the last runs of the first series the supply of ammonia was decreased and then shut off, and BOD removals fell to 19%. Higher hydraulic and organic loadings were probably partly responsible, but fungi partly replaced bacteria in the slime during this period.

The forced aeration filter observations also showed the advantage of added nutrients. The first four sets of runs in the first series form two pairs with comparable organic loadings but with and without added nutrients. Both the COD data and, after dropping the suspect observations (Table 2), the BOD data showed increased removals when

nutrients were added. The deficiency in nutrients could also have explained the poor performance of this filter in the elevated temperature runs of the second series.

The need for adding phosphorous to fruit canning wastes for efficient treatment was not shown by the experiments.

LOADING

The fresh waste strength as measured by the concentration of BOD, COD, or SS varied from day to day. Even so, hydraulic and organic loadings were highly correlated and their effects on removals are not completely separable. Percent removals generally declined with increasing organic load.

The pounds of BOD and of COD removed increased considerably with higher loadings. For loadings and removals both expressed as pounds/1000 cubic feet/day, BOD removal exceeded 1100 lbs at a loading of about 3500; and COD removal was almost 2300 lbs at a loading of about 5700 in the forced aeration filter. The maximum removal in the natural aeration filter was about 700 lbs of BOD, at the maximum loading of 1860 lbs.

TEMPERATURE

Elevated temperatures were not shown to improve the performance of the forced aeration filter under the conditions of these experiments. Heating system malfunctions prevented the maintenance of a constant elevated temperature, especially in the first series of runs. In addition, the temperature of the system dropped each weekend (generally for one day) when the cannery was not operating, no fresh waste was available, and the unit had to be switched to recycling only. Feed pump malfunctions cut off the added nutrients part way through the elevated temperature runs in the second series, and differences in hydraulic and organic loadings could account for some of the differences in removal efficiency in the temperature experiments. When nutrients were deficient, percent removals at ambient temperature (in the first series of runs) were better than those at elevated temperature (in the second series), considerably as measured by COD and slightly as measured by BOD. With added nutrients, the elevated temperature runs were superior to those at ambient temperature in the percentage removal of both BOD and COD, even though the highest

loadings were in the elevated temperature runs. The population density of thermophilic bacteria in the filter may never have reached a high enough concentration to provide the expected higher removal rates. Possibly these bacteria require trace elements (such as boron) that may have been lacking. Since the bios was not studied, the responsible factors are not known.

AERATION

The experiments did not show directly that forced aeration improved filter performance. The operational difficulties mentioned under temperature, above, may have obscured the beneficial effects of aeration. BOD removals increased with increased aeration at ambient temperatures, but a decreasing organic load in the same comparison may have been responsible. At elevated temperatures BOD removals decreased with increased aeration but nutrient deficiency was an interference. The dissolved oxygen (DO) concentration in the filter effluent was measured during the elevated temperature runs, and went up with increased aeration (dissolved oxygen data are in Appendix B). The DO was mostly zero and averaged 0.23 ppm with 100 standard cubic feet per minute (SCFM) aeration; it averaged 0.83 at 200 SCFM and 1.10 at 300 SCFM.

EFFECT ON pH

The highest percentage removals of BOD were accompanied by the least reductions in pH through the natural aeration filter. Comparisons when other important conditions were approximately constant were few for the forced aeration filter, but overall the same effect seemed to be indicated. The pH of both the fresh waste and the filter effluents was generally lower in the first than in the second series of runs; see Table 1 and Appendix B.

FILTER DEPTH

The second series of runs with the natural aeration filter provided information on removals and other waste characteristics at different filter depths. Data are in Table 3 and in the Appendix. The averages from the 14.4 foot depth in most of Table 3 are of fewer runs than the averages of the other two depths; but the overall averages in the bottom line of the table cover the same runs for all three depths.

Table 3. Trickling Filter Performance at Three Depths

gpm/sq. ft.		SS ppm				BOD lbs/1000 cu. ft./day								
			depth, feet			7.2 ft. depth			14.4 ft. depth			21.5 ft. depth		
fresh	recyc.	fresh	7.2	14.4*	21.5	load	remov.	%rem.	load	remov.	%rem.	load	remov.	%rem.
0.44	0.44	450	420	240	360	1550	580	42	920	550	60	520	240	45
.44	.44	550	730	-	820	1730	660	38	-	-	-	580	270	45
.44	.44	720	1240	1430	1130	1860	710	38	890	330	37	620	270	43
.44	.44	810	1450	1280	1620	1830	620	33	900	360	41	610	250	40
.44	.44	770	2020	1310	1350	1860	500	27	950	290	31	620	200	32
.44	.44	670	1540	1380	1460	1810	510	31	890	270	30	610	220	35
0.44	0.44	710	1410	1300	1290	1800	530	32	900	320	35	600	230	37

* 14.4 ft. data are based on fewer samplings than the others; the overall averages in the bottom line are directly comparable.

The top third of the column removed 32% of the BOD; the top two-thirds, 35%; and the whole filter, 37%. Of the BOD removed, about 80% was taken out by the top section, 15% by the middle section, and 5% by the bottom section. COD removals were similar. The top third of the filter removed 67% of the reducing sugars, more than twice as high a percentage removal as that of the total BOD. (Eighty-four percent of the BOD in the fresh waste was composed of reducing sugars.)

The DO concentration was maintained in the natural aeration filter at almost the same level by all three filter depths, slightly higher than the concentration in the effluent from the smaller filter with 300 SCFM of forced aeration. At comparable depths the natural aeration filter performed much better than the forced aeration filter. The fresh waste to both filters was identical, but the former generally operated at lower organic and hydraulic loadings than the latter.

It is concluded that, under the condition of this study, increasing the depth of the filter medium beyond 14 feet is not advantageous.

SECTION IV

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The Aerojet-General Corporation supplied the pilot forced aeration-controlled temperature trickling filter unit. Personnel of the company were instrumental in providing assistance in installation and operation of the unit:

Frank D. Ducey G.E. Rose K.E. Price

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Much of the credit for the success of this project must go to the team that carried out the tasks of operating the units, collecting the data and samples, and performing the analyses required to obtain the results. The project team included the following:

Carol Barnes
David Diosi
Larry Johnson
Charles Small
Brenda O'Flaherty
Bob Watkins
Tom Murphy

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Allen Katsuyama	Jack Ralls
Ron Tsugita	Stuart Judd
Norman Olson	Nabil Yacoub

Other contributions were made by many individuals concerned with the implementation of the project. We acknowledge the assistance given by these unnamed individuals and look forward to future cooperation in research projects which seek to find answers and solutions to halt the pollution of everyone's environment.

Walter A. Mercer
Project Coordinator

Walter W. Rose
Project Leader

SECTION V

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SECTION VI

GLOSSARY

BOD	Biochemical oxygen demand; usually BOD_5, meaning the demand measured in a five-day test; a common measure of pollutional strength.
COD	Chemical oxygen demand; a measure of pollutional strength determined more rapidly than BOD and usually roughly 50% greater than BOD.
DO	Dissolved oxygen
hydraulic loading	The quantity of liquid applied to a treatment system, usually measured in gallons per minute per unit of area.
organic loading	The quantity of BOD, COD, or other pollutional material applied to a treatment system; usually measured in pounds per unit of volume per day.
pH	The negative logarithm of the hydrogen ion concentration; a measure of the functional acidity or alkalinity of a liquid.
ppm	Parts per million
SCFM	Standard cubit feet per minute; a standardized measure of air flow.
SS	Suspended solids; insoluble material measured by filtering.

SECTION VII

APPENDICES

A. LABORATORY METHODS

Except as noted, laboratory determinations were carried out by the procedures described in:

> American Public Health Association, American Waterworks Association, and Water Pollution Control Federation. Standard Methods for the Examination of Water and Wastewater, 12th Edition, American Public Health Association (1965).

The methods used were:

> BOD as a five-day biochemical oxygen demand;
> COD, chemical oxygen demand, in the first series by the procedure in National Canners Association. Laboratory Manual for Food Canners and Processors, vol. 2, p. 352, Avi Publishing Company (1968); in the second series by the Jeris modification (Jeris, J.S. A Rapid COD Test, Water and Wastes Engineering 4 (5), 89-91 (1967);
> SS, suspended solids, by glass fiber filtration;
> pH by glass electrode; and
> DO, dissolved oxygen, by the sodium azide-Winkler method.

B. DETAILED DATA

Data on each of the daily composites for both filters and both series of studies are in the following tables. Table 7 repeats data from those runs listed in Table 6 when samples were drawn from all three depths of the natural aeration filter.

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Table 4. Natural Aeration Trickling Filter, First Series

Hydr. *		Influent						Effluent						Org. *	Removal *					
Raw	Rec.	COD ppm	BOD ppm	SS ppm	pH	DO, ppm AM	PM	COD ppm	BOD ppm	SS ppm	pH	DO, ppm AM	PM	Temp.	COD lbs	BOD lbs	COD lbs	COD %	BOD lbs	BOD %	Air SCFM	Nutr.
0.66	0.66	2130	1700	-	5.3			1250	900	-	5.2				790	630	320	41	300	47		
"	"	2930	2370	-	-			1670	1540	-	-				1080	880	470	43	310	35		
"	"	2500	1890	-	6.3			1410	980	-	6.4				920	700	400	44	380	48		
"	"	2810	2240	-	6.2			1350	980	1100	6.8				1040	830	540	52	650	79		
"	"	2350	1860	670	6.1			920	820	900	5.7				870	690	530	61	390	56		
"	"	1780	1100	280	7.9			1630	1080	120	5.6				660	410	60	9	10	2		
"	"	2900	800	490	6.4			1250	160	60	6.2				1080	300	610	57	240	80		
"	"	2530	1240	-	-			1130	850	-	-				940	460	520	56	150	32		
Ave. 0.66	0.66	2480	1640	480	6.0			1320	920	540	6.0				920	640	430	47	300	47		
0.88	0.88	3600	1790	-	7.5			2120	1540	-	5.1				1780	890	880	41	120	14		
"	"	2500	2060	-	5.0			2050	1920	672	4.9				1240	1020	220	18	70	7		
"	"	2840	1600	60	6.2			1420	1440	-	5.3				1400	800	700	50	80	10		
"	"	3400	1860	810	7.9			1500	1530	600	5.5				1680	920	940	56	160	17		
"	"	3180	2150	1030	6.4			1500	1650	680	5.2				1580	1060	830	53	250	24		
"	"	3260	2000	450	6.7			1430	1610	1060	5.5				1620	990	910	56	200	19		
"	"	2480	1800	620	8.1			1400	1400	720	5.5				1220	890	530	44	200	22		
"	"	2900	1940	670	8.8			1530	1500	1880	5.4				1440	960	680	48	220	22		
Ave. 0.88	0.88	3070	1900	670	7.1			1660	1580	940	5.3				1510	940	710	47	160	17		
0.88	0.88	2380	2250	670	7.5			1300	1430	910	6.8				1620	1120	980	60	400	36		N
"	"	3200	2330	550	8.6			1140	1040	330	6.7				1580	1150	1020	64	640	56		"
"	"	2870	2010	620	8.5			930	1270	740	6.6				1420	1000	960	68	360	36		"
"	"	3080	1840	710	8.3			1540	1700	1590	9.3				1520	910	760	50	70	8		"
"	"	3010	1940	600	6.0			1700	1820	910	6.1				1490	980	650	44	70	7		"
"	"	3420	2520	870	5.2			1740	1840	510	5.9				1690	1260	840	49	340	27		"
"	"	3260	2490	590	5.5			1260	1750	400	5.8				1600	1230	980	61	370	30		"
"	"	3390	-	830	6.2			1140	-	2530	6.5				1680	-	1120	66	-	-		"
"	"	3630	2410	950	6.1			1100	1190	1330	5.8				1800	1190	1290	72	600	50		"
Ave. 0.88	0.88	3240	2220	710	6.9			1320	1510	1030	6.6				1600	1100	960	60	360	31		N
1.54	1.54	3020	2180	600	6.8			1820	1650	380	6.5				2620	1880	1040	40	460	24		N**
"	"	3310	2310	800	6.6			2000	1720	840	6.4				2870	2000	1140	40	510	26		"
"	"	2980	800	-	-			1600	980	580	6.5				2580	690	1200	46	(-170)	-		"
"	"	3250	2020	1040	4.8			1910	1560	820	4.6				2820	1740	1170		390	22		"
"	"	2640	1710	1190	6.6			1730	1250	930	5.0				2280	1480	790	35	400	27		"
"	"	4980	1450	560	7.8			1690	960	540	5.6				4310	1250	2850	66	430	34		"
"	"	2290	1580	440	5.2			1300	1520	400	4.7				1990	1370	850	43	(-50)	-		"
"	"	2040	1450	400	4.9			1100	1270	470	4.7				1760	1260	810	46	160	13		"
"	"	2680	1260	560	8.4			1160	880	390	5.6				2330	1090	1320	57	330	30		"
"	"	2040	1620	530	5.5			930	1300	600	4.9				1780	1400	960	54	270	20		"
1.54	1.54	2920	1640	680	6.3			1520	1310	600	5.5				2530	1420	1210	47	270	19		N**

* Hydraulic load (raw and recycle) in gal./min/sq ft; organic load and pounds removal in lbs/1000 cu ft/day.

** Decreasing nutrient addition.

Table 5. Forced Aeration Trickling Filter, First Series

Hydr. * Raw	Hydr. * Rec.	Influent COD ppm	Influent BOD ppm	Influent SS ppm	Influent DO, ppm pH	Influent DO, ppm AM	Influent DO, ppm PM	Influent Temp.	Effluent COD ppm	Effluent BOD ppm	Effluent SS ppm	Effluent DO, ppm pH	Effluent DO, ppm AM	Effluent DO, ppm PM	Effluent Temp.	Org. * COD lbs	Org. * BOD lbs	Removal * COD lbs	Removal * COD %	Removal * BOD lbs	Removal * BOD %	Air SCFM	Nutr.
0.39	0.64	2500	1890	-	6.3			83	1750	1540	-	5.2			76	1510	1160	450	30	210	18	300	
"	1.26	3400	1860	810	7.9			85	2170	1770	1180	5.5			74	2110	1150	880	42	50	5	"	
"	"	3180	2150	1030	6.4			85	1810	2010	1490	5.5			79	1980	1330	860	43	90	7	"	
.42	.76	2810	2240		6.2			78	1840	1510	-	5.5			76	1900	1520	660	35	500	33	"	
.45	.36	2900	800	490	6.4			83	1590	1100	200	5.9			75	2100	-	940	45	-	-	"	
.47	.35	1780	1100	280	7.9			85	1590	1080	520	5.3			86	1340	850	150	11	20	2	"	
"	.38	2350	1860	670	6.1			81	990	830	840	5.7			80	1770	1400	1020	58	780	56	"	
Ave. 0.42	0.72	2700	1700	650	6.7			83	1680	1410	850	5.5			77	1820	1240	710	38	270	20	300	
0.72	1.24	2840	1600	-	6.2			83	1730	1540	-	5.2			80	3280	1850	1280	39	80	4	300	
.74	.27	2530	1240	-	-			82	1690	1140	-	-			78	3000	1460	1000	33	120	8	"	
.84	.68	3210	2010	-	-			86	1540	1420	-	-			78	4320	2700	2250	52	790	29	"	
.85	.97	2500	2060	-	5.0			83	1240	1310	-	5.2			79	3380	2800	1700	50	1020	36	"	
.92	1.08	3600	1790	-	7.5			82	2690	1620	-	5.6			77	5310	2640	1350	25	270	10	"	
Ave. 0.81	0.86	2940	1740	-	6.2			83	1780	1410	-	5.3			79	3860	2200	1520	40	500	20	300	
0.27	1.18	3260	2490	590	5.5			108	1318	1740	560	5.2			80	1410	1080	840	60	330	30	300	N, P
.36	1.70	3250	2020	1040	4.8			104	1990	1550	1990	4.5			94	1880	1160	730	39	270	23	"	"
.45	1.50	3280	2250	670	7.5			120	1860	1840	1080	5.5			101	2370	1630	1050	44	300	18	"	"
.57	.97	2040	1620	530	5.5			107	870	1170	910	4.8			107	1860	1470	1060	57	410	28	"	"
Ave. 0.41	1.34	2960	2100	710	5.8			110	1510	1575	1140	5.0			96	1880	1340	920	50	330	25	300	N, P
0.65	1.04	3420	2520	870	5.2			109	1780	2170	820	5.1			95	3560	2520	1700	48	350	14	300	N, P
.68	"	2980	770	-	6.5			103	1080	860	-	5.9			92	3220	-	2060	64	-	-	"	"
.69	1.27	2900	1940	670	8.8			120	1810	1500	1550	5.5			105	3230	2170	1220	38	500	23	"	"
"	1.01	2680	1260	560	8.4			117	540	1360	830	5.0			102	2990	1400	2390	80	(-100)	-	"	"
.84	.54	3010	1940	600	6.0			97	2200	2000	440	5.2			94	4040	2600	1090	27	(-100)	-	"	"
.38	1.05	2040	1450	400	4.9			117	850	1570	1340	4.8			103	2700	1920	1580	58	(-140)	-	"	"
Ave. 0.73	0.99	2840	2230	620	6.6			111	1380	1830	1000	5.2			99	3290	2120	1670	52	100	5	300	N, P
0.90	1.18	3080	1840	710	8.3			100	1260	980	680	6.0			93	4450	2660	2640	59	1250	47	300	N, P
.92	"	3880	2310	900	6.7			122	2930	2130	1210	6.2			115	5720	3400	1410	25	270	8	"	"
.94	.95	2290	1580	440	5.2			117	1710	1220	1530	5.0			103	3440	2380	870	25	550	23	"	"
.95	1.20	3630	2410	950	6.1			105	2250	2080	980	5.3			99	5510	3660	2100	38	500	14	"	"
1.01	1.01	3020	2180	600	6.8			99	2040	1900	1270	5.5			95	4890	3530	1580	32	450	13	"	"
"	"	3310	2310	800	6.6			110	2170	2000	1930	5.6			101	5360	5330	1850	34	450	13	"	"
.99	1.20	3390	-	830	6.2			118	1723	1820	1470	5.4			110	5410	-	2660	49	-	-	"	"
1.04	1.54	2870	2010	620	8.4			100	810	720	2500	5.9			95	4770	3320	3470	73	2120	64	"	"
1.06	1.20	2480	1800	620	8.1			116	2200	1470	930	6.3			104	4240	3060	470	11	560	18	"	"
Ave. 0.98	1.16	3110	2060	720	6.9			110	1900	1590	1390	5.7			102	4870	3170	1890	39	770	25	300	N, P
1.13	0.85	-	1450	-	-			108	-	1070	-	-			104	-	2620	-	-	690	26	300	N, P
1.17	1.50	3200	2330	550	8.6			111	1550	1670	960	6.5			93	6000	4390	3090	52	1250	28	"	"
1.29	.57	2640	1710	1190	7.1			116	1930	990	860	6.6			110	5450	3530	1460	27	1480	42	"	"
Ave. 1.20	0.97	2920	1830	870	7.8			112	1740	1240	910	6.6			106	5720	3510	2280	39	1140	32	300	N, P

* Hydraulic load (raw and recycle) in gal. /min/sq ft; organic load and pounds removal in lbs/1000 cu ft/day.

Table 6. Natural Aeration Trickling Filter, Second Series *

Run	INFLUENT						EFFLUENT												1/3 Filter depth						3/3 Filter depth					
							1/3 Filter depth						3/3 Filter depth						Loading**		Removal**				Loading**		Removal**			
	COD ppm	BOD ppm	SS ppm	pH	DO AM	ppm PM	COD ppm	BOD ppm	SS ppm	pH	DO AM	ppm PM	COD ppm	BOD ppm	SS ppm	pH	DO AM	ppm PM	COD lbs	BOD lbs	COD lbs	COD %	BOD lbs	BOD %	COD lbs	BOD lbs	COD lbs	COD %	BOD lbs	BOD %
a	4800	2500	420	7.8			3600	1500	300	8.1			3100	1200	220	8.0			3540	1840	880	25	730	40	1190	620	420	35	320	52
b	2700	1800	150	8.6			1600	1000	190	8.4			1500	900	160	8.2			1990	1330	810	41	590	44	670	440	300	45	220	50
c	3100	2100	250	8.4			2100	1500	200	7.8			1900	1300	200	8.0			2290	1550	740	32	440	28	770	520	300	39	200	38
d	3700	2000	600	8.5			2200	1500	600	7.6			2000	1300	500	7.6			2730	1480	1110	41	370	25	910	490	420	46	170	35
e	3600	1900	700	8.7			1800	1000	700	8.9			1900	900	700	8.8			2660	1400	1330	50	660	47	890	470	420	47	250	53
f	3500	2300	550	8.5			2100	1400	550	8.6			1900	1300	400	8.4			2580	1700	1030	40	670	39	860	570	390	45	250	44
AVE	3570	2100	450	8.4			2230	1320	420	8.2			2050	1130	360	8.2			2630	1550	980	38	580	42	880	520	380	43	240	45
g	3100	2200	370	7.9			2100	1500	510	7.7			1900	1300	550	7.2			2290	1620	740	32	510	32	770	540	300	39	220	41
h	4000	2800	600	8.1			2300	1700	410	7.8			2100	1500	360	7.5			2950	2070	1250	42	820	40	990	690	470	48	320	46
i	3400	2200	550	7.8			2000	1300	700	8.1			1800	1100	500	7.7			2510	1620	1030	41	660	41	840	540	400	48	270	50
j	3000	2000	550	7.4			2000	1300	650	7.7			2000	1300	600	7.6			2210	1480	730	33	520	35	740	490	250	34	170	35
k	3500	2500	700	7.2			2000	1400	1400	7.5			1900	1200	2100	7.2			2580	1840	1100	43	810	44	860	620	390	45	320	52
AVE	3400	2340	550	7.6			2080	1440	730	7.8			1940	1270	820	7.4			2510	1730	970	38	660	38	840	580	360	43	270	45
l	4000	2700	800	7.7			2300	1400	1000	8.0			2100	1300	800	8.0			2950	1990	1250	42	960	48	990	670	470	48	350	52
m	4100	2700	690	7.5			2900	1900	1400	7.5			2300	1600	1000	7.4			3020	1990	880	29	490	30	1010	670	440	44	270	40
n	4600	2800	840	7.8			2300	1200	1900	7.3			2200	1300	2300	7.1			3390	2070	1690	50	1180	57	1140	690	600	53	370	54
o	4000	2300	750	7.8	4.4	2.9	2400	1400	980	7.8	2.2	1.9	2100	1400	850	7.7	2.0	1.2	2950	1700	1180	40	670	39	990	570	470	48	220	39
p	4900	2400	700	7.9	3.1	3.9	2500	1600	1200	7.9	2.2	2.4	2300	1400	950	7.8	1.9	2.4	3610	1770	1770	49	590	33	1210	590	640	53	240	41
q	3500	2200	550	8.0	3.7	-	2900	1800	980	7.9	1.5	-	2300	1500	850	7.6	1.3	-	2580	1620	440	17	290	18	860	540	290	34	170	32
AVE	4180	2520	720	7.8	3.7	3.4	2550	1550	1240	7.7	1.9	2.2	2220	1420	1130	7.6	1.7	1.8	3080	1860	1200	38	710	38	1030	620	480	46	270	43

Table 6. Natural Aeration Trickling Filter, Second Series, continued *

Run	INFLUENT						EFFLUENT												1/3 Filter depth						3/3 Filter depth					
							1/3 Filter depth						3/3 Filter depth						Loading**		Removal**				Loading**		Removal**			
	COD	BOD	SS		DO	ppm	COD	BOD	SS		DO	ppm	COD	BOD	SS		DO	ppm	COD	BOD	COD	COD	BOD	BOD	COD	BOD	COD	COD	BOD	BOD
	ppm	ppm	ppm	pH	AM	PM	ppm	ppm	ppm	pH	AM	PM	ppm	ppm	ppm	pH	AM	PM	lbs	lbs	lbs	%	lbs	%	lbs	lbs	lbs	%	lbs	%
r	4400	2500	560	7.7	-	3.3	3200	2000	1800	7.8	-	1.8	2800	1800	1200	7.3	-	1.5	3250	1840	890	27	360	20	1090	620	400	37	180	29
s	4300	2600	980	7.7	2.0	2.1	3000	1800	2000	7.2	0.5	1.7	2800	1800	2500	7.5	0.3	0.3	3170	1920	950	30	590	31	1060	640	370	35	270	42
t	4000	2600	600	8.0	2.3	2.2	2600	1600	1600	7.6	1.1	1.0	2600	1600	2800	7.2	0.5	0.3	2950	1920	1030	35	740	38	910	640	270	30	240	38
u	4200	--	750	7.4	1.9	2.2	2500	--	1600	7.9	1.8	1.0	2300	--	2700	7.3	0.7	0.9	3100	--	1260	41	--	-	1040	--	470	45	--	-
v	3600	1900	570	7.6	3.1	2.4	2100	1200	1000	8.2	2.0	1.6	1900	1000	1300	8.2	2.6	2.4	2660	1400	1110	42	510	36	890	470	420	47	220	47
w	4400	2200	730	7.5	-	3.2	2500	1400	1500	8.0	-	2.6	2400	1400	1200	7.8	-	2.5	3250	1620	1410	43	590	36	1090	540	500	46	190	35
x	4300	2800	760	7.6	-	2.6	3400	2000	880	8.2	-	1.5	3000	1600	500	7.7	-	1.9	3170	2070	660	21	490	28	1060	690	320	30	290	42
y	4300	2600	790	7.7	3.4	3.1	2600	1700	1300	7.8	2.4	2.1	2300	1600	1000	7.5	3.4	2.5	3170	1920	1250	39	670	35	1060	640	490	46	240	38
z	3900	2600	1400	7.7	2.7	2.6	2400	1400	1400	6.6	2.1	1.4	2200	1200	1400	6.6	1.5	1.4	2880	1920	1110	38	890	46	960	640	420	44	340	53
AVE	4160	2480	810	7.7	2.5	2.6	2700	1640	1450	7.7	1.7	1.6	2480	1490	1620	7.5	1.2	1.5	3070	1830	1070	35	620	33	1020	610	410	40	250	40
aa	3900	2500	760	7.3	-	2.9	2700	1700	1600	6.7		1.0	2500	1500	2100	6.3	-	1.5	2880	1840	890	31	590	32	960	620	340	35	250	40
bb	4300	2400	660	7.3	2.1	2.6	3000	1800	2200	6.5	1.5	0.2	2700	1800	1900	6.4	0.6	0.2	3170	1770	950	30	440	25	1060	590	390	37	150	25
cc	4100	2700	950	7.4	-	2.4	3000	1800	820	7.1	-	1.6	2700	1600	370	6.9	-	2.2	3020	1990	800	26	550	33	1010	670	340	34	270	40
dd	4300	2500	560	7.3	2.5	2.1	3000	1900	1900	5.9	1.3	0.6	2900	1800	1200	5.7	1.9	1.1	3170	1840	950	30	440	24	1060	620	340	32	180	29
ee	4500	2500	900	6.9	1.8	1.8	3400	2000	3600	5.5	0.5	0.6	3500	1900	1200	5.6	1.2	0.9	3320	1840	810	24	360	20	1110	620	250	22	150	24
AVE	4220	2520	770	7.2	2.1	2.3	3020	1840	2020	6.3	1.1	0.8	2860	1720	1350	6.2	1.2	1.2	3110	1860	890	28	500	27	1040	620	330	32	200	32
ff	4200	2800	790	7.5	-	2.9	2600	1800	2200	6.0	-	1.0	2100	1400	1000	5.8	-	0.9	3100	2070	1180	38	740	36	1040	690	420	50	340	49
gg	3900	3000	800	8.8	-	-	2600	1700	1400	6.1	-	-	2000	1400	830	6.5	-	-	2880	2210	960	33	960	43	960	740	470	49	390	53
hh	4400	2700	830	8.1	-	2.4	2500	1500	400	7.8	-	-	2100	1300	230	7.6	-	3.0	3250	1990	1410	43	880	44	1090	670	570	52	350	52
ii	--	--	--	-	3.5	2.9	2300	1400	--	7.2	2.4	1.6	2200	1600	--	7.0	3.2	2.8	--	--	--	-	--	-	--	-	--	-	--	-
jj	4200	2500	650	7.8	1.6	1.5	3000	1800	870	6.3	1.2	0.7	2300	1700	1100	5.9	2.0	1.1	3100	1840	880	28	510	28	1040	620	470	45	200	32
kk	3400	2100	650	7.6	2.1	-	2900	2000	1100	5.7	1.0	-	2700	1800	1400	5.6	1.0	-	2510	1550	370	15	70	45	840	520	170	20	80	15
ll	3600	2100	570	7.1	-	3.9	2600	1800	1600	5.5	-	0.0	2600	1600	1400	5.4	-	0.2	2660	1550	740	28	220	14	890	520	250	28	120	23
mm	3100	2100	570	8.5	2.1	-	2700	1600	2100	6.1	0.1	-	2300	1500	3000	5.5	0.0	-	2290	1550	300	13	370	24	770	520	200	26	150	29
nn	3700	2400	590	7.5	-	1.9	2800	1800	2400	5.9	-	0.0	2600	1700	2800	5.9	-	0.0	2730	1770	660	24	440	25	910	590	270	30	170	29
oo	3800	2400	600	7.6	-	2.3	2900	1900	1800	6.3	-	0.1	2500	1600	1400	6.0	-	0.9	2800	1770	660	24	370	21	940	590	320	34	190	32
AVE	3810	2460	670	7.8	2.3	2.5	2690	1730	1540	6.3	1.0	0.8	2340	1560	1460	6.1	1.6	1.3	2810	1810	800	27	510	31	940	610	360	37	220	35

* Fresh and recycle hydraulic loads both 0.44 gallons per minute per square foot; nitrogen added.

** Organic load and pounds removal in lbs/1000 cu ft/day.

Table 7. Natural Aeration Trickling Filter, Second Series, Depth Comparisons *

Run	COD, ppm				BOD, ppm				Suspended Solids				pH				DO, ppm							
		Filter depth				Filter depth				Filter depth				Filter depth				Filter depth						
	Influent	1/3	2/3	3/3	Influent	1/3	2/3	3/3	Influent	1/3	2/3	3/3	Influent	1/3	2/3	3/3	Influent	1/3		2/3		3/3		
a	4800	3600	2700	3100	2500	1500	1000	1200	420	300	244	244	7.8	8.1	8.2	8.0	AM	PM	AM	PM	AM	PM	AM	PM
b	4100	2900	2800	2300	2700	1900	1600	1600	690	1400	1105	1000	7.5	7.5	7.4	7.3								
c	4000	2400	2200	2100	2300	1400	1300	1400	750	980	2200	850	7.8	7.8	7.5	7.7	4.4	2.9	2.2	1.9	2.2	1.4	2.0	1.2
d	3500	2900	2500	2300	2200	1800	1600	1500	550	980	1000	850	8.0	7.9	7.4	7.6	3.7		1.5		1.5		1.3	
e	4400	3200	3000	2800	2500	2000	1800	1800	560	1800	1200	1200	7.7	7.8	7.4	7.3		3.3		1.8		1.7		1.5
f	4000	2600	2700	2600	2600	1600	1600	1600	600	1600	1600	2800	8.0	7.6	7.3	7.2	2.3	2.2	1.1	1.0	1.4	0.9	0.5	0.3
g	3600	2100	2000	1900	1900	1200	1100	1000	570	1000	1100	1300	7.6	8.2	8.1	8.2	3.1	2.4	2.0	1.6	2.2	2.3	2.6	2.4
h	4400	2500	2500	2400	2200	1400	1500	1400	730	1500	1800	1200	7.5	8.0	7.9	7.8		3.2		2.6		2.6		2.5
i	4300	3400	3000	3000	2800	2000	1500	1600	760	880	570	500	7.6	8.2	7.9	7.7		2.6		1.5		1.4		1.9
j	3900	2400	2300	2200	2600	1400	1200	1200	1400	1400	1400	1400	7.7	6.6	6.6	6.6	2.7	2.6	2.1	1.4	1.4	0.6	1.5	1.4
k	3900	2700	2600	2500	2500	1700	1600	1500	760	1600	1600	2100	7.3	6.7	6.6	6.3		2.9		1.0		1.3		1.5
l	4100	3000	2800	2700	2700	1800	1800	1600	950	820	720	370	7.4	7.1	6.9	6.9		2.4		1.6		1.8		2.2
m	4500	3400	3200	3500	2500	2000	1900	1900	900	3600	1600	1200	6.9	5.5	5.7	5.6	1.8	1.8	0.5	0.6	1.2	1.1	1.2	0.9
n	3900	2600	2100	2000	3000	1700	1600	1400	800	1400	1400	830	8.8	6.1	6.1	6.5								
o	4400	2500	2300	2100	2700	1500	1600	1300	830	400	325	230	8.1	7.8	7.6	7.6		2.4		2.0		2.3		3.0
p	4200	3000	2400	2300	2500	1800	1600	1700	650	870	560	1100	7.8	6.3	6.0	5.9	1.6	1.5	1.2	0.7	1.0	0.6	2.0	1.1
q	3400	2900	2800	2700	2100	2000	1900	1800	650	1100	1200	1400	7.6	5.7	5.7	5.6	2.1		1.0		1.1		1.0	
r	3600	2600	2400	2600	2100	1800	1500	1600	570	1600	1800	1400	7.1	5.5	6.0	5.4		2.2		0.8		0.5		0.8
s	3100	2700	2700	2300	2100	1600	1700	1500	570	2100	2000	3000	8.5	6.1	5.8	5.5	2.1		0.1		0.1		0	
t	3700	2800	3000	2600	2400	1800	1900	1700	590	2400	2100	2800	7.5	5.9	6.0	5.9		1.9		0		0		0
u	3800	2900	2900	2500	2400	1900	1700	1600	600	1800	1700	1400	7.6	6.3	5.9	6.0		2.3		0.1		0.4		0.9
AVE	3980	2810	2610	2500	2440	1700	1570	1520	710	1410	1300	1290	7.7	7.0	6.9	6.8	2.6	2.4	1.3	1.2	1.3	1.3	1.3	1.4
% Removal		29	34	37		30	36	38																
% Increase										99	83	82												

Table 7. Natural Aeration Trickling Filter, Second Series, Depth Comparisons, continued *

Run	1/3 Filter Depth						2/3 Filter Depth						3/3 Filter Depth					
	Loading**		Removal**				Loading**		Removal**				Loading**		Removal**			
	COD	BOD	COD	COD	BOD	BOD	COD	BOD	COD	COD	BOD	BOD	COD	BOD	COD	COD	BOD	BOD
	lbs	lbs	lbs	%	lbs	%	lbs	lbs	lbs	%	lbs	%	lbs	lbs	lbs	%	lbs	%
a	3540	1840	880	25	730	40	1770	920	770	44	550	60	1190	620	420	44	320	52
b	3020	1990	880	29	490	30	1510	1000	480	32	410	41	1010	670	440	44	270	40
c	2950	1700	1180	40	670	39	1480	850	660	45	370	44	990	570	470	48	220	39
d	2580	1620	440	17	290	18	1290	810	370	29	220	27	860	540	290	34	170	32
e	3250	1840	890	27	360	20	1620	920	520	32	260	28	1090	620	400	37	180	29
f	2950	1920	1030	35	740	38	1480	960	480	32	370	38	910	640	270	30	240	38
g	2660	1400	1110	42	510	36	1330	700	590	44	300	43	890	470	420	47	220	47
h	3250	1620	1410	43	590	36	1620	810	700	43	260	32	1090	540	500	46	190	35
i	3170	2070	660	21	590	28	1590	1030	480	30	480	47	1060	690	320	30	290	42
j	2880	1920	1110	38	890	46	1440	960	590	41	520	54	960	640	420	44	340	53
k	2880	1840	890	31	590	32	1440	920	480	33	330	36	960	620	340	35	250	40
l	3020	1990	800	26	660	33	1510	1000	480	32	330	33	1010	670	340	34	270	40
m	3320	1840	810	24	360	20	1660	920	480	29	220	24	1110	620	250	22	150	25
n	2880	2210	960	33	960	43	1440	1110	660	46	520	47	960	740	470	49	390	53
o	3250	1990	1410	43	880	44	1620	1000	770	48	410	41	1090	670	570	52	350	52
p	3100	1840	880	28	510	28	1550	920	660	43	330	36	1040	620	470	45	200	32
q	2510	1550	370	15	70	45	1250	770	220	18	70	9	840	520	170	20	80	15
r	2660	1550	740	28	220	14	1330	770	440	33	220	29	890	520	250	28	120	23
s	2290	1550	300	13	370	24	1140	770	150	13	150	20	770	520	200	26	150	29
t	2730	1770	660	24	440	25	1360	890	260	19	180	20	910	590	270	30	170	29
u	2800	1770	660	24	370	21	1400	890	330	24	260	29	940	590	320	34	190	32
AVE	2940	1800	860	29	530	32	1470	900	500	34	320	35	980	600	360	37	230	37

* Fresh and recycle hydraulic loads both 0.44 gallons per minute per square foot; nitrogen added.
** Organic load and pounds removal in lbs/1000 cu ft/day.

Table 8. Forced Aeration Trickling Filter, Second Series

Hydr. load		Influent							Effluent							Load *		Removal *					
Raw gpm/ft²	Recyc. gpm/ft²	COD ppm	BOD ppm	SS ppm	pH	DO AM	ppm PM	Temp °F	COD ppm	BOD ppm	SS ppm	pH	DO AM	ppm PM	Temp. °F	COD #s	BOD #s	COD #s	%	BOD #s	%	Air SCFM	Nutr.
0.54	0.90	4800	2500	420	7.8			81	4100	1900	240	7.6			80	4170	2170	610	15	520	24	100	N, P
0.57	1.13	2700	1800	150	8.6			84	2400	1600	140	7.0			84	2460	1640	270	11	180	11	100	"
0.54	1.08	3100	2100	250	8.4			80	2600	1800	150	7.4			80	2690	1820	430	16	260	14	100	"
0.54	1.08	3700	2000	600	8.5			81	2800	1800	650	6.8			80	3210	1740	780	24	180	10	100	"
0.54	1.08	3600	1900	700	8.7			81	3400	1900	1100	10.5			80	3130	1650	180	6	0	0	100	"
0.59	1.08	3500	2300	550	8.5			81	2700	1900	900	9.2			80	3290	2160	750	23	370	17	100	"
Ave. 0.55	1.06	3570	2100	450	8.4			81	3000	1820	530	8.1			80	3160	1860	500	16	238	13	100	N, P
0.54	1.08	3100	2200	370	7.9			80	2700	2100	700	6.1			80	2690	1910	350	13	90	5	200	N, P
0.54	1.08	4000	2800	600	8.1			80	3000	2300	800	6.3			80	3470	2430	870	25	430	18	200	"
0.54	1.08	3400	2200	550	7.8			81	2500	1800	600	6.2			81	2950	1910	780	26	350	18	200	"
0.36	1.08	3000	2000	550	7.4			80	2400	1900	700	5.5			80	1740	1160	350	20	60	5	200	"
0.23	1.08	3500	2500	700	7.2			81	2500	1800	1600	5.2			81	1270	900	370	29	250	28	200	"
Ave. 0.44	1.08	3400	2340	550	7.6			80	2620	1980	880	5.8			80	2420	1660	540	23	244	15	200	N, P
0.23	1.08	4000	2700	800	7.7			76	2400	1600	1100	6.4			75	1450	980	580	40	400	41	300	N, P
--	--	4100	2700	690	7.5			-	--	--	--	-			-	--	--	--	-	--	-	300	"
0.45	1.08	4600	2800	840	7.8			81	4100	2700	720	6.6			80	3330	2030	360	11	80	4	300	"
0.45	1.08	4000	2300	750	7.8	4.4	2.9	83	2900	1900	900	5.9	2.2	2.5	83	2890	1660	790	27	290	18	300	"
--	--	4900	2400	700	7.9	3.1	3.9	-	2900	2000	860	5.6	2.2	2.6	-	--	--	--	-	--	-	300	"
0.45	0.90	3500	2200	550	8.0	3.7	-	-	2600	1700	780	5.1	0.9	-	-	2530	1590	650	26	360	23	300	"
Ave. 0.40	1.03	4180	2520	720	7.8	3.7	3.4	80	2980	1980	870	5.9	1.8	2.6	79	2550	1570	660	26	333	21	300	N, P

Table 8. Forced Aeration Trickling Filter, Second Series, continued

Hydr. load		Influent							Effluent							Load *		Removal *					
Raw gpm/ft²	Recyc. gpm/ft²	COD ppm	BOD ppm	SS ppm	pH	DO AM	ppm PM	Temp °F	COD ppm	BOD ppm	SS ppm	pH	DO AM	ppm PM	Temp °F	COD #s	BOD #s	COD #s	%	BOD #s	%	Air SCFM	Nutr.
0.45	1.08	4400	2500	560	7.7	-	3.3	122	--	--	--	-	-	0.0	121	3180	1810	--	-	--	-	100	N, P
0.50	0.90	4300	2600	980	7.7	2.0	2.1	118	4200	2200	1000	6.0	0.0	0.0	114	3420	2070	80	2	320	16	100	"
0.54	0.90	4000	2600	600	8.0	2.3	2.2	112	3300	2000	6500	5.6	0.0	0.0	112	3470	2260	600	17	520	23	100	"
0.45	0.90	4200	--	750	7.4	1.9	2.2	117	3500	--	3100	5.1	0.0	0.0	115	3040	--	510	17	--	-	100	"
0.54	0.90	3600	1900	570	7.6	3.1	2.4	122	3300	1800	2200	6.0	0.0	0.0	122	3130	1650	260	8	90	6	100	"
0.54	0.90	4400	2200	730	7.5	-	3.2	121	3200	1800	625	5.4	-	0.0	120	3820	1910	1040	27	350	18	100	"
0.50	0.90	4300	2800	760	7.6	-	2.6	114	3900	2200	1900	6.9	-	0.8	112	3420	2230	320	9	480	22	100	"
0.50	0.90	4300	2600	790	7.7	3.4	3.1	118	3500	2300	750	6.7	0.7	0.6	119	3420	2070	550	16	240	12	100	"
0.50	0.90	3900	2600	1400	7.7	2.7	2.6	112	3400	1900	500	6.4	0.5	0.8	111	3100	2070	390	13	560	27	100	"
Ave. 0.50	0.92	4160	2480	810	7.7	2.5	2.6	117	3550	2020	2070	6.0	0.2	0.2	116	3330	2010	465	14	352	18	100	N, P
0.54	0.90	3900	2500	760	7.3	-	2.9	116	3600	1900	750	6.5	-	0.8	114	3390	2170	260	8	520	24	200	N, P**
0.54	0.90	4300	2400	660	7.3	2.1	2.6	115	3700	2200	670	6.0	0.2	0.9	115	3730	2080	520	14	170	8	200	"
0.54	0.90	4100	2700	950	7.4	-	2.4	117	4000	2300	700	6.8	-	1.2	117	3560	2340	90	2	340	14	200	"
0.50	0.90	4300	2500	560	7.3	2.5	2.1	120	3200	2100	810	5.7	0.2	1.1	121	3420	1990	870	25	320	16	200	"
0.50	0.90	4500	2500	900	6.9	1.8	1.8	120	4100	2200	1000	5.7	1.0	1.0	118	3580	1990	320	9	240	12	200	"
Ave. 0.52	0.90	4220	2520	770	7.2	2.1	2.3	117	3720	2140	790	6.1	0.4	1.0	117	3540	2110	420	12	310	15	200	N, P**
0.45	0.90	4200	2800	790	7.5	-	2.9	110	3600	2300	650	5.8	-	1.6	106	3040	2030	440	14	370	18	300	N, P**
0.45	0.90	3900	3000	800	8.8	-	-	85	--	--	--	-	-	-	83	2820	2170	--	-	--	-	300	"
0.45	0.90	4400	2700	830	8.1	-	2.4	105	3700	2300	480	7.1	-	1.1	108	3180	1950	500	16	290	15	300	"
0.45	0.90	--	--	--	-	3.5	2.9	104	--	--	--	-	1.5	1.1	112	--	--	--	-	--	-	300	"
0.50	0.90	4200	2500	650	7.8	1.6	1.5	105	3500	2200	630	5.8	0.5	0.8	109	3340	1990	550	16	240	12	300	"
0.45	0.90	3460	2100	650	7.6	2.1	-	109	3100	2000	600	6.1	1.0	-	109	2460	1520	220	9	70	5	300	"
0.54	0.90	3600	2100	570	7.1	-	3.9	108	3600	2200	510	5.8	-	1.8	110	3130	1820	--	-	--	-	300	"
0.54	0.90	3100	2100	570	8.5	2.1	-	110	2900	1900	580	5.8	1.0	-	108	2690	1820	170	6	170	9	300	"
0.50	0.90	3700	2400	590	7.5	-	1.9	114	3200	2000	540	5.6	-	1.2	108	2940	1910	160	5	320	17	300	"
0.54	0.90	3800	2400	600	7.6	-	2.3	106	3400	2100	530	5.7	-	1.4	104	3300	2080	350	11	260	12	300	"
Ave. 0.49	0.90	3810	2460	670	7.8	2.3	2.5	106	3380	2130	570	6.0	1.0	1.3	106	2990	1920	331	11	242	13	300	N, P**

* Organic load and pounds removal in lbs/1000 cu ft/day.

** Decreasing nutrient addition.

* U. S. GOVERNMENT PRINTING OFFICE : 1972—484-484/154

1 Accession Number	2 Subject Field & Group	SELECTED WATER RESOURCES ABSTRACTS INPUT TRANSACTION FORM
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5 Organization

National Canners Association, Berkeley, California

6 Title

TRICKLING FILTER TREATMENT OF FRUIT PROCESSING WASTE WATERS

10 Author(s)

Mercer, Walter A.
Rose, Walter W.

16 Project Designation

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Forced aeration - controlled temperature trickling filter

27 Abstract

Two high rate trickling filters were evaluated for treating fruit canning liquid wastes; one was 7.5 feet deep and had provision for heating the treated waste and for forced aeration; the other was 21.5 feet deep and was operated at ambient temperatures and with natural aeration; both were packed with a high void ratio plastic medium.

Nitrogen added to the cannery waste improved the removal of BOD and COD. In the absence of added nitrogen a thick fungal slime developed with odors characteristic of anaerobic microbial action. More often than not, percent removals declined with increasing organic loadings; the pounds of BOD removed per unit volume increased with high loadings. Elevated temperatures were not consistently shown to improve the performance of the experimental filter. Forced aeration was not proven beneficial but maintained higher levels of dissolved oxygen.

The top third of the 21.5 foot trickling filter accomplished 80% of the filter's total BOD removal under a light hydraulic loading. The natural aeration filter maintained a slightly higher dissolved oxygen concentration in the effluent than did the experimental filter with forced aeration.

Abstractor Walter W. Rose | Institution National Canners Association, Berkeley, California

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